Spatial analysis of biomass and N accumulation of a winter wheat cover crop grown after a drought-stressed corn crop in the SE coastal plain

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Interpretive summary

Variability in corn growth due to soil map unit differences throughout a field causes variation for residual fertilizer N. We conducted this study to determine the site-specific effects of soil variation on the ability of a wheat cover crop to grow and trap N following a drought-stricken corn crop. We found that in areas where corn yield was greatest, wheat growth and N accumulation were uniformly high. On the other hand, there was a wide range in wheat growth and N accumulation in areas of the field with the lowest corn yield. The low corn yields occurred primarily near depression areas, called Carolina Bays. Thus, wheat cover crops should be more effective and reliable in reducing N losses to the environment and building soil organic matter away from the Carolina Bays.

Key words: residual nitrogen fertilizer, site-specific management, spatial variability, wheat biomass.

*ABSTRACT: Spatial variability in crop yield can cause large within-field differences in fertilizer N removal. Cereal winter cover crops can trap the residual N, but their ability to do so partially depends on the soil conditions that determine growth. Our objective was to determine site-specific effects of soil variation on biomass and N accumulation by a wheat (*Triticum aestivum *L.) cover crop that was grown after a droughted corn (*Zea maize *L.) crop. In 1993, corn was grown with an applied fertilizer N rate of 129 kg ha^{-1} on an 8-ha field near Florence, SC. Nitrogen removed by grain at 10 locations (representing six soil types) ranged from 14 to 41 kg N ha^{-1}. Wheat was planted in November without additional fertilizer N. Wheat biomass and N content were measured on 15 March, 15 April, and 14 May. Inorganic soil N to a depth of 90 cm was measured on 22 March 1994 and ranged from 49 to 95 kg ha^{-1}. By mid-March, wheat accumulated 49% of its total N but only 14% of its biomass of that measured in May. After mid-April, significant increases in N accumulation occurred at only two sites. Biomass accumulation by mid-May ranged from 2032 to 7914 kg ha^{-1} and N accumulation ranged from 19 to 52 kg ha^{-1}. The amount of variability among sites for wheat biomass was greater than the amount of variability among sites for N. Variation for wheat biomass and N accumulation within soil map units was similar to the amount of variation among soil map units. Most of the variability was caused by differences in sites within and among soils associated with depression areas. Around these depression areas, site-specific management of N inputs appears more effective than cover crops at reducing N losses to the environment. Away from these areas, cover crops should be predictable and reliable in trapping N and increasing soil organic matter.*

Corn grain yields often fail to meet grower expectations because of biotic and abiotic stresses. Since N fertilizer is applied at levels to provide enough N to meet the crop demand for those yield expectations, there is often considerable residual N left in the soil after corn harvest. Cover crops have the potential to scavenge the residual fertilizer N. In doing so, they may reduce this economic loss to growers and the potential environmental risk to groundwater (Shipley et al. 1992). However, their ability to grow (and scavenge N) will be dictated by inherent soil conditions.

Camberato and Frederick (1994) recently demonstrated that winter wheat could scavenge considerable residual N from a preceding corn crop when grown for grain on a Coastal Plain soil. Fields in this region are highly variable, with many soil map units and a range of physical and chemical properties that influence crop growth (Karlen et al. 1990). An understanding of the within-field variability for N scavenging ability by a cereal cover crop would help determine its utility for scavenging N.

Many of the fields in the southeast coastal plain contain depression areas called Carolina Bays. The soils in and around the bays are often less productive than those throughout the rest of the fields and are the cause of a large amount of yield variation each year. The field where this study was conducted has two of these bays. We have described the spatial variability for soil water, canopy temperature, crop phenology, and yield of a droughted corn crop in a southeast coastal plain field (Sadler et al. 1995). The differences in grain yield within and between soil map units in 1993 (1300 to 3300 kg ha^{-1}) presumably left variation in residual fertilizer N across the field. We hypothesized that this would cause differences in cover crop growth, thus providing us a unique opportunity to make a spatial assessment of biomass accumulation and N scavenging by a winter cover crop.

Winter wheat was chosen so that the long-term rotation established on the field could be maintained. Our objective was to measure site-specific effects of soil variation on N accumulation by a wheat winter cover crop that was grown after a droughted corn crop.

Materials and methods

Specific details of the corn production in this field in 1993 are given by Sadler et al. (1995). Clemson University Cooperative Extension recommendations for nonirrigated corn production were used. Planting date was 9 April. Nitrogen fertilization consisted of a preplant broadcast application of 17 kg N ha^{-1} on 30 March and a sidedress application of 112 kg N ha^{-1} on 28 May. Corn was harvested from 16 to 24 September. Ten ears from two randomly chosen places in each of the sites were hand-harvested and mechanically shelled. Grain samples were dried at 70°C, ground, and stored until laboratory analysis.

[1] Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

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Corn stalks were shredded with a rotary mower and the field was disked twice before planting wheat. 'Coker 9835' wheat was sown on 17 November with a 3.05-m wide Case-IH model 5100 grain drill.[1] Row spacing was 17.8 cm and 108 kg seed ha^{-1} was planted. No fertilizer or pesticides (besides seed treatment) were used in the production of the wheat.

Four soil map units were monitored at two different places in the field for wheat growth and N accumulation. The soil types and site designation were: sites 1 and 2, Goldsboro loamy fine sand (GoA; fine-loamy, siliceous, thermic Aquic Paleudult); sites 3 and 4, Norfolk loamy sand (NkA; fine-loamy, siliceous, thermic Typic Kandiudult); sites 5 and 6, Bonneau loamy fine sand (BnA; loamy, siliceous, thermic Arenic Paleudult); and sites 7 and 8, Coxville loam (Cx; Clayey, kaolinitic, thermic Typic Paleaquult). Two soil map units were also monitored at one site each. These were: site 10, Nobocco fine sandy loam (NfA; fine loamy, siliceous, thermic Typic Paleudult) and site 11, Norfolk that had a thicker surface horizon than NkA (NoA; thick surface, fine-loamy, siliceous, thermic Typic Kandiudult).

In an effort to determine the amount of soil N that was available just before the wheat began rapid spring growth, two randomly selected 2-m^2 areas were sampled for soil N analysis at each site on 22 March 1994. Using a 2.5-cm diameter soil tube, three soil cores in each area were collected to a depth of 90 cm, air-dried on a greenhouse bench, ground, and stored until laboratory analysis. Aboveground wheat biomass and N content were measured on 15 March, 15 April, and 14 May in 1994. On these dates, four areas around each of the ten sites were randomly selected. The four samples at each site consisted of all aboveground plant tissue in 30-cm row sections of six adjacent rows that were near the middle of a drill pass. Plant samples were dried at 70°C, weighed, ground, and stored until analysis.

Soil NO_3-N and NH_4-N were determined by extracting samples with 2 M KCl and measuring ion concentrations in the extracts with a QuikChem® 8000 Automated Ion Analyzer[1] (Lachat Instruments, Milwaukee, WI). Nitrogen concentration in the wheat plant tissue and corn grain was determined by digesting samples with H_2SO_4 and measuring total N in the sample digests with a Technicon Autoanalyzer II Continuous Flow System (Bran+Lubbe Co., Buffalo Grove, IL).

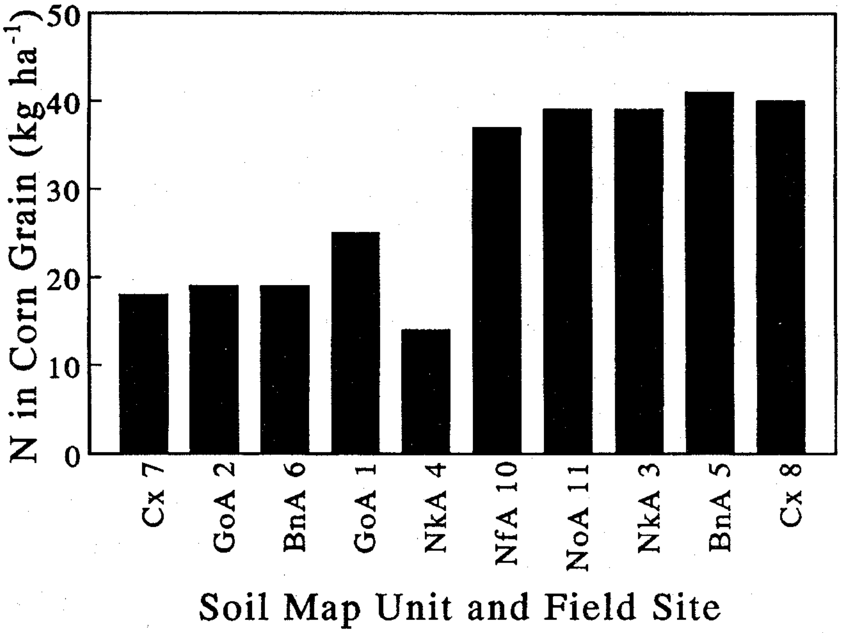

Figure 1. Corn grain N removed from 10 sites in an 8-ha field near Florence, SC in 1993
NOTE: X-axis labels are the soil map unit and the assigned number of the site in the study; sites were arranged on the x-axis in order from lowest to highest corn yield

Corn grain yield values reported by Sadler et al (1995) were multiplied by the grain N concentration to determine N removal from each site at harvest. Biomass was multiplied by N concentrations to determine wheat N accumulation.

Data were subjected to analysis of variance and soil N, wheat biomass, and N content site means were separated by calculating a least significant difference (LSD) using a 0.10 α level. Rainfall and temperature data were collected with instruments that were located next to the field.

Results and discussion

Although corn grain yields were low due to the extended drought in 1993, substantial differences in yield occurred among the 10 sites. The two Coxville soil map unit sites (sites 7 and 8) had both the lowest and the highest corn grain yields during 1993. Yield at site 7 was 1283 kg ha^{-1} while site 8 had a yield of 3274 kg ha^{-1} (Sadler et al. 1995). The relatively high yield for site 8 may be an anomaly. The area around this site was recently disturbed during land forming around a

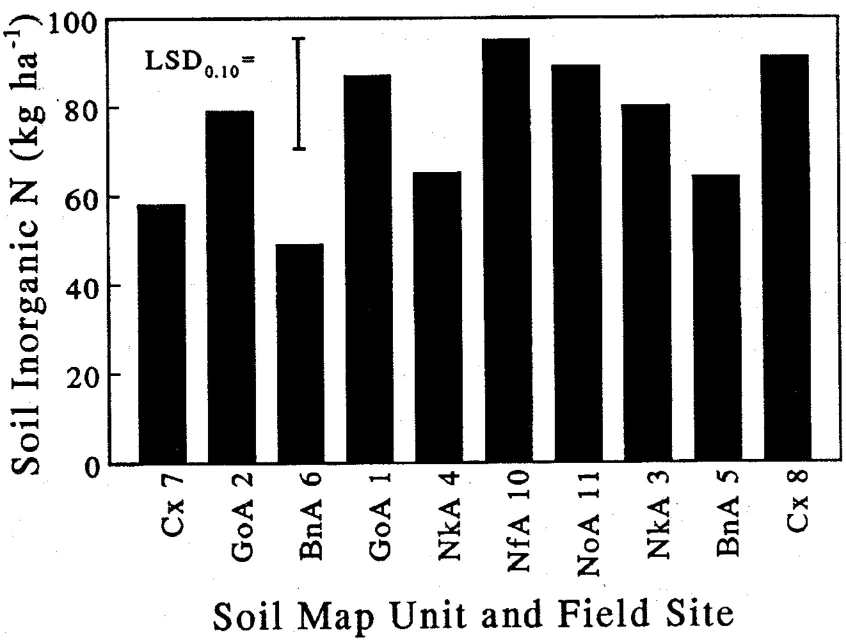

Figure 2. Soil inorganic N amounts in the surface 90 cm at 10 sites in an 8-ha field near Florence, SC on 22 March, 1994

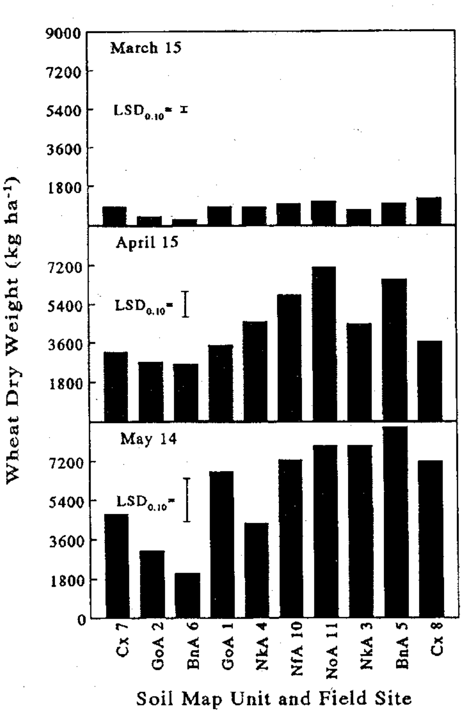

Figure 3. Wheat biomass at 10 sites for three sampling dates in 1994

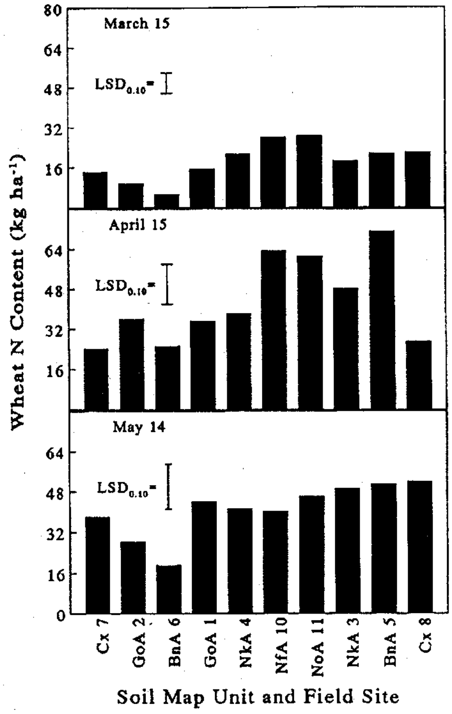

Figure 4. Amount of N in aboveground biomass of wheat at 10 sites for three sampling dates in 1994

drainage culvert. Although there were no differences in the two Cx sites in horizon depths or textures, differences in soil compaction may have been largely due to the disturbance. In addition, Sadler et al. (1995) found water from other areas ran onto site 8 during rainfall events. Corn grain yield ranking for the rest of the sites (lowest to highest) was GoA site 2, BnA site 6, GoA site 1, NkA site 4, NfA, site 10, NoA site 11, NkA site 3, and BnA site 5. For purposes of presentation, the x-axis of Figures 1 through 4 have been arranged so that the sites are in order from lowest corn grain yield to highest. The site numbers are the same as those used by Sadler et al (1995).

Five of the 10 sites had corn N grain removal of around 20 kg ha^{-1}, while five had grain N removal of around 40 kg ha^{-1} (Figure 1). These differences were primarily due to differences in yield since corn grain N content was similar among sites, ranging from 12.5 g kg^{-1} at site 8 to 14.9 g kg^{-1} at site 10. Variation within soil types for N removal by the grain was considerable, with the exception of the Goldsboro soil (sites 1 and 2) which only differed by 6 kg N ha^{-1}. For the NkA, BnA, and Cx soils, differences between sites were greater than 20 kg N ha^{-1}.

Even though soil map unit was not a good indicator of N removal by the corn grain, some of the variation in the field can be explained by relative location to a Carolina Bay. Four of the five areas where grain N removal was low were from areas in or around one of the two bays in the field. The exception was site 4 which was a Norfolk soil some distance from either bay. The only site among the five that had relatively high corn grain N removal that was located near a bay was the Cx site 8, which may have been an anomaly as explained earlier.

Though the 1993 corn season was dry, weather conditions for the 1993-94 wheat crop were not unusual. Rainfall during the wheat growing season was well spaced and adequate. No large rainfall events (all less than 50 mm) occurred between corn harvest and wheat planting. Few daily temperature extremes occurred.

Total soil inorganic N for the surface 90 cm at each of the sites is shown in Figure 2. Inorganic N ranged from 50 kg ha-1 at site 6 to 96 kg ha^{-1} at site 10. Most of the inorganic N at each site was NH_4-N, because total NO_3-N ranged from only 6 kg ha^{-1} at site 4 to 20 kg ha^{-1} at site 6 (data not shown). The concentrations of NO_3-N levels were similar to those found previously by Karlen et al. (1990) in this field in 1986 and 1988. Among the five sites with low corn grain N removal, three (sites 4, 6, and 7) had significantly lower inorganic N concentrations than the site with the highest inorganic N levels (site 10). Conversely, only the BnA soil map unit (site 5) had significantly lower inorganic N levels than site 10 among the five sites with high grain N removal.

Wheat biomass accumulation for the three sampling dates in the spring of 1994 is shown in Figure 3. At mid-March, biomass accumulation ranged from 260 kg ha^{-1} at site 6 to 1234 kg ha^{-1} at site 8. Variability for growth at that time was greater among the five sites that had low corn grain N removal than among the five sites that had high grain N removal. Most of the wheat biomass accumulation occurred between mid-March and mid-April (Figure 3). Growth between mid-April and mid-May was highly site-specific. Biomass accumulation was less than 1000 kg ha^{-1} between mid-April and mid-May

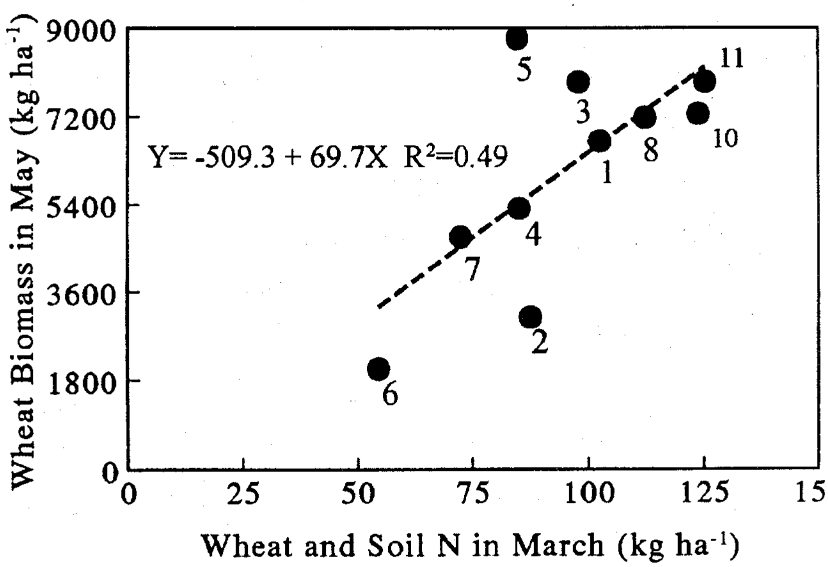

Figure 5. Relationship between wheat biomass in mid-May and the amount of soil inorganic N plus wheat N determined in mid-March
NOTE: Numbers in the figure correspond to the sites in the field

for the sites that had the lowest (sites 2, 4, and 6) and the site that had the highest (site 11) biomass accumulation in mid-April. Between mid-April and mid-May at the other six sites, wheat growth was greater than 1400 kg ha^{-1} (ranging from 1440 kg ha^{-1} at site 10 to 3540 kg ha^{-1} at site 8). There was only one soil map unit (Cx, sites 7 and 8) where both sites studied had large biomass increases between these dates.

As occurred for corn yield, variation within a soil map unit for wheat biomass was almost as great as variation among soil map units. In fact, the two BnA sites (5 and 6) had both the highest and the lowest mean wheat biomass production at the 13 May sampling date. Interestingly, a wide variation in wheat growth (from 1800 to 7200 kg ha^{-1}) occurred among the five sites that had low corn grain N removal. Among the five sites where grain N removed was higher, wheat biomass was relatively uniform (Figure 3). The high values (greater than 7200 kg ha^{-1}) are similar to the mid-April biomass levels measured by Frederick and Bauer (1996) the same year in a wheat grain crop fertilized with 90 kg N ha^{-1}.

Wheat N accumulation at the three sampling dates is shown in Figure 4. There was a wide range in percent of total N accumulation among sites at the 15 March sampling date (the range was 27% at site 6 to 70% at site 10). The greatest within-soil-map unit difference occurred for the BnA soil where total N accumulated was only 5 kg ha^{-1} at site 6 and 22 kg ha^{-1} at site 5. Averaged over all sites, biomass at the March sampling date was 14% of the May sampling date. In contrast, average N accumulation at the March date was 49% of the May sampling date, and five of the sites had already accumulated over 50% of the total N that they would scavenge by mid-May. Wheat N accumulation did not increase substantially between mid-April and mid-May at any but the two Coxville sites. At mid-April, the two Coxville sites had accumulated only 62% (site 7) and 52% (site 8) of the total N they had accumulated by mid-May.

Although variation for wheat N accumulation was quite large at both the mid-March and mid-April sampling dates among these 10 sites, variability at mid-May for total N in the aboveground plant tissues was small (Figure 4). Site 6 was somewhat lower than the sites with the highest N accumulation levels; otherwise, sites did not differ. Loss of leaves in the faster growing, earlier maturing sites (sites 5, 10, and 11), coupled with the later growth of the Cx soil (sites 7 and 8) tended to eliminate much of the variability that occurred at the earlier sampling dates.

Because the areas with greatest corn yield also tended to be the areas with greatest wheat biomass production, there was not a negative correlation between N removal by the corn grain and wheat biomass production. Nitrogen losses to the environment from the more productive sites may have been lower than the other sites because the sites with the highest corn grain yield also tended to have the highest amount of combined soil inorganic N and wheat N in March. This combined N amount was related to wheat biomass in May. About 50% of the variation in wheat biomass production among the sites in May was explained by the total amount of N (soil inorganic N plus wheat N) that was measured in March (Figure 5, $P = 0.02$ for regression).

In summary, soil map unit was a poor indicator of wheat growth and N scavenging. Proximity to a bay was a fairly good indicator, though exceptions did occur. Since this data set was from one growing season only, it is not clear whether these exceptions are numerous enough and of sufficient magnitude to warrant more detailed analysis. Since areas around the bays were as a group less productive for both corn production and for wheat growth and N scavenging, site-specific management of N inputs will probably be more effective than cover crops at reducing N losses to the environment from these field areas. However, at sites not associated with the bays, wheat growth and N scavenging were relatively uniform. In terms of land area, these soils are predominate over the bay areas in most fields in the Coastal Plain and using cover crops to trap N and to increase soil organic matter should be predictable and reliable for those areas.

REFERENCES CITED

Camberato, J.J., and J.R. Frederick. 1994. Residual maize nitrogen availability to wheat on the southeastern coastal plain. Agron. J. 86:962-967.

Frederick, J.R., and P.J. Bauer. 1996. Winter wheat responses to surface and deep tillage on the southeastern coastal plain. Agron. J. 88:829-833.

Karlen, D.L., E.J. Sadler, and W.J. Busscher. 1990. Crop yield variation with coastal plain soil map units. Soil Sci. Soc. Am. J. 54:859-865.

Sadler, E.J., P.J. Bauer, and W.J. Busscher. 1995. Spatial corn yield during drought in the southeast coastal plain. pp. 365-381. In Site-Specific Management for Agricultural Systems. Proc. 2nd Workshop. ASA/CSSA/SSSA, Madison, WI.

Shipley, P.R., J.J. Meisinger, and A.M. Decker. 1992. Conserving residual corn fertilizer nitrogen with winter cover crops. Agron. J. 84:869-876.